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MATURITY INDICES FOR GRAND FIR CONES

Robert D. Pfister[1]

ABSTRACT

Cones collected at 10-day intervals were used to evaluate possible indices of cone maturity. Although both specific gravity and moisture content decreased with maturity, specific gravity was the better indicator of the actual stage of maturity. Adherence of seed to cone scales and color of seed wings also appeared promising as qualitative indices.

Improvement of grand fir (Abies grandis (Dougl.) Lindl.) seed quality is needed for successful and economical reforestation programs. Past regeneration efforts have been hampered by poor seed quality that has been attributed to several causes, including premature cone collection, improper storage of cones and seed, and injury to seed during cleaning. Premature cone collection is probably the most important single factor for grand fir because collectors have not had adequate guidelines for determining maturity in the field.

Past studies have shown that seed can be extracted more economically from mature cones and has a higher germinability than seed from immature cones (18). It has also been demonstrated that completely mature seed retains its viability during storage better than immature seed does (7, 23). Thus, agencies involved with tree seed collection need a reliable index for determining cone maturity. Such an index must be not only objective and applicable in the field, but should also be definitive to the extent of indicating the degree of maturity.

[1]Research Forester, headquartered at Forestry Sciences Laboratory, Moscow, Idaho, which is maintained in cooperation with the University of Idaho. The author wishes to thank Dr. Te May Ching, Oregon State University, for making available the facilities of the University's seed research laboratory, and Dr. J. H. Rediske, Weyerhaeuser Timber Company, for supplying a copy of his manuscript on seed maturity in noble fir.

Specific gravity of cones has been tested more widely than any other index as a means to assess cone maturity (2, 3, 4, 7, 8, 9, 10, 13, 14, 19, 20, 22, 23). This measure has proved quite reliable for most species. For species where specific gravity is poorly related to seed maturity, other criteria may be needed.

Many other techniques have been used to evaluate maturity. Moisture content has been related to cone maturity for grand fir, Douglas-fir, and Colorado spruce (1, 2, 3). Qualitative characteristics that have also been tested as indices of maturity include: cone color (5, 8, 10, 13, 19, 22), cone firmness (5), and seed color and firmness (5, 22). One study showed that time of cutting by squirrels was related to cone maturity in Douglas-fir (12). The usefulness of this relationship is questionable because, as Maki (13) states, squirrels are chiefly interested in the carbohydrates of the endosperm--not in the germinative energy of the embryo.

The increasing demand for grand fir seed for reforestation has magnified the problem of obtaining mature, viable seed. When 1961 proved to be a good year for grand fir seed production in northern Idaho, we capitalized on this as an opportunity to begin a study of possible maturity indices. The work was done in conjunction with another study involving artificial cone-ripening techniques (15).

METHODS

Cones were collected from grand fir trees in a mature, mixed conifer stand in the Deception Creek area of the Coeur d'Alene National Forest. The stand is on a northerly slope at about 3,200 feet elevation within a habitat that is ecologically characterized as *Thuja-Tsuga/Pachistima* (6). Cones were collected six times at 10-day intervals from July 25 to September 13, 1961, by felling two or three trees on each collection date. The cones were covered with damp muslin to prevent desiccation during transport to the Deception Creek Experimental Forest headquarters.

Immediately after each collection, observations were recorded on cone color and firmness, seed color and firmness, and seed wing color. Twenty sound cones were also selected, weighed, immersed in water in a graduate cylinder to determine volume, and ovendried at 105° C. until constant dry weight was obtained. Specific gravity and moisture content were computed from these values.

An additional 20 sound cones from each collection date were placed on racks in an open shed to dry before seed extraction. These cones were separated into two replicates containing 10 cones each.

On October 25, after 6 to 12 weeks of cone storage (depending on the particular collection date), seeds were extracted, screened to remove the scales, hand-rubbed to remove the seed wings, and cleaned with a small fan. Cleaning did not remove the empty seeds. The cleaned seed was then stored at about 1° C. for approximately 1 month. Six 100-seed samples of the cleaned seed from each collection date were then stratified between layers of damp peat moss at about 1° C. for 26 days prior to the germination tests.

Evaluation of seed weight and germination tests began in early January.[2] Fresh weight was determined for two 100-seed samples of stratified and unstratified seed from each collection date. Dry weight and moisture content were determined for one 100-seed sample of unstratified seed from each collection date.

[2]All seed weight and germination tests were conducted in the seed physiology laboratory at Oregon State University.

Germination tests were conducted on six 100-seed samples of stratified and two 100-seed samples of unstratified seed from each collection date using plastic petri dishes containing "Sponge Rok."[3] Alternating temperatures of 20° C. (16 hours daily in the dark) and 30° C. (8 hours daily with light) were maintained during these tests. Germination counts were made at 2- or 3-day intervals for 30 days. Ungerminated seeds were cut to determine whether they were filled, empty, or woody. If seeds were filled, tetrazolium chloride was used to establish apparent viability.

Ten seedlings, approximately 5 days old, were selected to represent each sample of stratified seed. Length of each seedling was measured, and each 10-seedling group was weighed to provide means for comparing early vigor.

RESULTS

Seed maturity increased as collection dates approached the time of natural seed fall (table 1). Germinative capacity[4] and seed dry weight increased, while seed moisture content decreased--during the period up to and including the final collection--when cones were beginning to shed their seed naturally. Unstratified seeds from the August 15 collection germinated very slowly, but the rate of germination for later collections was uniformly rapid. Date of collection did not affect seedling vigor as measured by total length. The increase in seedling weight probably reflects normal seed weight trends.

Table 1.--Measures of seed maturity and resulting seedling vigor by cone collection dates

Collection date[1]	Seed maturity				Seedling vigor	
	Germinative capacity	Dry weight	Moisture content	Rate of germination[2]	Length	Weight
	Percent	Gms./100 seeds	Percent	Days	Mm.	Gms./10 seedlings
August 4	0.0	[3]1.35	11.4	--	--	--
August 15	30.3	1.74	9.0	24.1	35.6	0.690
August 24	29.4	1.71	9.6	9.0	40.3	.778
September 3	53.8	2.56	8.3	11.0	39.7	.902
September 13	71.2	2.67	7.2	11.4	38.3	.959

[1]Seeds from the July 25 collection shriveled during storage and were not extracted.
[2]Number of days required for germination of nonstratified seed to reach 50 percent of germinative capacity.
[3]Any means connected by brackets are not significantly different ($P < 0.05$) by Duncan's Multiple Range Test.

[3]Material produced by Paramount Perlite Co., Paramount, California. Trade names given here are for purposes of identification only and do not constitute an endorsement by the U.S. Forest Service.

[4]Includes those seeds that actually germinated plus the seeds that the tetrazolium test indicated were viable. The latter usually amounted to less than 2 percent.

Cone specific gravity and moisture content decreased with later collection dates (table 2). After August 4, the decrease in specific gravity was quite uniform and reached an observed low of 0.88 on September 3. Change in average moisture content was small (13 percent) during the observed period but showed a definite downward trend, although considerable variation was present. Cones were breaking up on the last collection date, September 13, so no cone measurements could be made. Sufficient data were not available to determine the degree of correlation between specific gravity and germination.

Seed wing color and degree of seed attachment seem to be the most promising qualitative indicators of maturity. Seed wing color progressed from green to purple, and became brown prior to the last two collections (table 2). When cones were broken apart for examination on September 3, the seed fell away from the scales. Prior to this date, seeds were attached firmly to the cone scales. These two changes were first observed in the September 3 collection and they correspond with the relatively high germinative capacity of seed collected on that date.

Cones were firm and of dark green color until the September 3 collection, at which time they had some brown-tipped scales and were easily compressed when squeezed by hand. However, maggot-infested cones exhibited the same characteristics prior to their disintegration about August 24. Seeds were milky in the early collections and firm in the last three collections. Color of seeds did not differ appreciably after the second collection date. Cotyledons had differentiated to the point at which they were readily distinguishable by the September 3 collection.

DISCUSSION

Total number of seeds was used as the basis for calculating germinative capacity because the proportion of empty, woody, and filled seeds varied with collection date. Many seeds from the early collections, apparently normal at time of collection, shriveled before the germination tests were run. Also, there was no clear distinction between woody seeds and empty seeds.

Germinability of grand fir seed improved until the time of seed dispersal. This behavior differed somewhat from the usual pattern of coniferous seed maturity wherein germinability increases rapidly in early collections and then levels off prior to seed dispersal.

Table 2.--Comparison of seed maturity with cone characteristics and seed wing color

Collection date	Germinative capacity	Cone specific gravity	Cone moisture content	Seed wing color
	Percent		Percent of fresh wt.	
July 25	[1] --	[2] 1.00	74.2	Green with purple tip
August 4	0.0	1.02	67.3	All purple
August 15	30.3	1.00	64.5	All purple
August 24	29.4	0.96	64.7	All purple
September 3	53.8	0.88	61.2	Mostly brown
September 13	71.2	--	--	Brown

[1] Seeds from the July 25 collection shriveled during storage and were not extracted.

[2] Any means connected by brackets are not significantly different ($P < 0.05$) by Duncan's Multiple Range Test.

The germinative capacity of seed from the August 24 collection was much lower than expected. Low specific gravity and rapid rate of germination indicated that the cones were quite close to maturity; this was further indicated by lack of response to artificial cone-ripening treatments (15). Some of the trees selected for collection on that date may have been ineffectively pollinated or inherently poor quality seed producers. An unexplained similar depression in the germination curve for noble fir seed (10) collected repeatedly from the same trees indicates that other factors may also be responsible.

Average moisture content and average specific gravity of cones both followed the expected pattern of decrease with time, but are not strictly related. Moisture content of cones varied greatly among trees. Because of this variation and the small amount of change during the period studied, cone moisture content appears less reliable than specific gravity as a quantitative index of maturity. Moreover, specific gravity is preferred as an index because it is easier to determine.

Cone color and cone firmness both indicated maturity. All immature cones in the study area were green, but in some areas color of immature cones reportedly varies from yellowish green to purplish (11). Color and firmness are difficult to define or measure. Also, insect-infested cones may discolor and lose firmness prior to maturity. Thus, these two qualitative criteria could easily lead inexperienced cone collectors to erroneous determinations of maturity.

Seed color darkened by the second collection date and seeds became firm by the third collection. However, both of these measures lack the precision necessary to define maturity adequately.

Changes in color of seed wings appeared to be directly related to seed maturity. However, color differences were observed for the green variety of cones only, so further testing should be done before this relationship can be recommended as a sole guide to seed maturity.

A logical and simple maturation test was provided where seeds fell away from the cone scales when the cones were broken apart. Although the time remaining for collection may be less than 10 days, the seed should be near the maximum possible germinative capacity.

RECOMMENDATIONS

As a result of this study the following recommendations are made for collecting grand fir cones to obtain high quality seed:

1. Cones should not be collected until their average specific gravity is less than 0.90.[5]
2. Cones may be collected when seeds are no longer attached firmly to the scales.
3. In areas where immature cones are green, cones may be collected when the seed wing color changes from purple to brown.

Additional study to provide a more critical index of degree of seed maturity would be desirable. Embryo development, including cotyledon differentiation as observed in this study and embryo elongation as reported for Douglas-fir (2, 8) is worthy of exploration. Length of cone storage should also be considered in future maturity studies since its effect has been demonstrated for noble fir (16) and Douglas-fir (17).

[5]A container of olive oil (or a half-and-half mixture of S.A.E. 20 motor oil and linseed oil) may be carried in the field. Mature cones (specific gravity < 0.90) will float and immature cones will sink. Sound cones from several trees in each collection area should be tested.

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